Potential Failure Modes Analysis (PFMA) – Insights and Lessons Learned for the Foundation of a Successful Dam Safety Management Program

Frank L. Blackett, P.E.
frank.blackett@ferc.gov
Federal Energy Regulatory Commission
Division of Dam Safety and Inspections
San Francisco Regional Office

Douglas D. Boyer, P.E., C.E.G
douglas.boyer@ferc.gov
Federal Energy Regulatory Commission
Division of Dam Safety and Inspections
Risk-Informed Decision Making Branch

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Thanks

- Co-author Doug Boyer
- The Federal Energy Regulatory Commission
Qualifying Statements

• The opinions expressed in this paper are those of the authors and do not necessarily represent official guidance or direction from the Federal Energy Regulatory Commission.

• Please refer to the paper for more detailed discussion than can be presented here today.
Purpose of this Paper

Why this paper?
Doesn’t everyone know what a PFMA is?
Isn’t this all old news?

- Been in use by dam safety industry for more than 20 years
  - Doesn’t everyone understand it now?

- Well used and understood by those using quantitative risk
  - Bureau of Reclamation and US Army Corps of Engineers

- Unfortunately, there are a lot of dam owners and consultants still not using the PFMA process or not using it to its full capability
PFMA Process

• There are FERC PFMA$s that do not meet the minimum standard.
  – High hazard potential dams owned by individuals
  – Dam owners without engineers overseeing their dams
  – Inconsistent application by regulators, owners, consultants
  – We are working on improving PFMA$s

• Possible reasons for not meeting minimum standard
  – Do not understand full benefit of detailed PFMA$s
  – Cost to do a detailed PFMA
  – Time to prepare
  – Ignorance is bliss?
  – Have never had problems at their dam
  – Think they understand the process, but need more training

So how do we get this message out to these folks?
Purpose of this Paper

• Convey the critical importance of performing a complete, accurate, and detailed PFMA.

• Clarify the process to those not intimately familiar with a PFMA.

• Emphasize the importance of developing a detailed PFM.

• Provide the author’s opinions and experiences in developing PFMFs and participating in PFMAs.

• Clarify that there is no prescriptive “cookbook” approach to a PFMA, as long as the “spirit of the law” is met.
The PFMA Process
Purpose of a PFMA

• Determine all possible ways a dam can fail*
  – Critical thinking is encouraged to find potential flaws

* For FERC projects, this includes uncontrolled release of water, Could include operational failures resulting in economic losses, or the failure of a design feature to operate as designed.
Benefits of the PFMA Process

• PFMs provide a good understanding of how your dam functions and could fail – the **foundation** of any dam safety program.

• Results of the information discovered during a PFMA will be used to develop a dam safety program

• Focus on understanding the design and performance of dam.

• Learn the intimate details about your dam.
Benefits of the PFMA Process

• Focuses the surveillance and monitoring plan
  – Defines what you need to monitor
  – Helps define performance parameters
  – Identifies risk reduction measures
  – Identifies previously unknown flaws
  – Could identify possible weaknesses in dam design and/or monitoring program
Preparing for a PFMA
PFMA Preparation

• Which comes first? The PFMA or inspection?
  – All participants in the PFMA should have visited the site.
  – May not initially require a detailed inspection.
  – May require additional site visit or review of PFMA.
  – No long lapse of time between the inspection and PFMA

• PFMA Participants
  – One or more facilitators
  – One or more note-takers
  – Project personnel:
    » Engineers, managers, operators
  – Consultants / subject matter experts (as required)
  – Regulators (as applicable)
PFMA Preparation

• Owner
  – Provide project documents to PFMA team well in advance
  – Provide hard copies of documents at PFMA
  – Work with facilitator to ensure all electronic equipment is working
  – Frequent breaks
  – Encourage providing snacks and beverages
PFMA Preparation

• Equipment/Facilities
  – Multiple projectors, computers, screens
    » One for note taker to develop PFM,
    » One to display background maps/information for discussion
    » Other equipment noted above
    » Well-lit room with adequate space

Check arrangement of:
1. Chairs
2. Tables
3. Screen
4. Materials

Try out any unfamiliar equipment you will use
PFMA Preparation

- Individual Team Members
  - Do your homework – read all available project documents
  - Make notes of possible PFMs during preparatory reading
  - Come prepared to fully participate and share ideas
  - Participate in all sessions of the PFMA
  - Ask lots of questions to develop full understanding
  - Develop your own list of PFMs
PFMA Preparation

• Facilitator(s)
  – Must be experienced in PFMA process
  – Read and become familiar with all project documentation
  – Individually brainstorm PFM(s) to ensure complete PFM discussion
  – Ensure proper equipment ready and available for workshop
    » Computer (s)
    » Projector (s) and screen (s)
    » Whiteboard or paper flipcharts
    » Full-size drawings and project documents
    » Note taker
PFMA Preparation

• PFMA is only as good as everyone’s preparation and the amount of effort put forward
Facilitation of PFMA

• Facilitator – possibly the most critical element of PFMA

  – Facilitate the following activities:
    » brainstorming session, per loading condition per project feature, to list general failure mechanisms (Normal, hydrologic, seismic)*
    » Prioritization of PFMs per loading condition
    » Fully develop prioritized PFMs
    » Discuss reasons why each PFM is likely or unlikely
    » Discuss risk reduction measures
    » For FERC projects, assign Category

* See Appendix of paper for items to consider
Facilitation of PFMA

- For FERC PFMAs, the facilitator should help select the voting members to assist in selecting PFM categories *

* Categories not used when doing risk
Facilitator

• The facilitator can make or break the PFMA process

• Qualities of a good facilitator
  – Independent and Objective
  – Experienced in the PFMA Process
  – Understands how to properly develop a detailed PFM
  – Knowledge of Dam Safety and Case Histories
  – Interrogator
  – Motivational Speaker
  – Referee
Facilitator

• Qualities of a bad facilitator*
  – Opinionated
  – Directs discussion towards their bias and decisions
  – Makes statements that discourage participation
    » Convince me that it’s a valid PFM and we will discuss it
    » There is no sense in discussing that
    » I have checked into that and it is not possible

• It is critical for the facilitator not to make any decisional type of statement that will bias the process

*Also bad qualities of any team member
Various Types of PFMAs
Types of PFMAs

- Initial PFMA
- PFMA Review
- Design PFMA
- Construction PFMA
Types of PFMAs

• Initial PFMA
  – First PFMA for a project
  – Requires review of all design documentation, construction records, performance and monitoring information
  – Full team of experts representing all aspects of the project
  – Include project operator(s)
Types of PFMAs

• Initial PFMA

• PFMA Review
  – Review of previously completed PFMA
  – Are all PFMs fully developed?
    » Fully described? All factors fully documented?
    » Are the PFMs separate and individual?
  – Review past performance and operation of facility
    » Any new information come to light since last review?
    » Instrumentation changes?
    » Operational changes?
  – Any new risk reduction measures?
  – Any new surveillance and monitoring requirements?
Types of PFMAs

- Initial PFMA
- PFMA Review

- Design PFMA
  - Used to evaluate design concepts, address deficiencies, and ensure design does not result in new dam safety deficiencies
  - Can also include post-construction PFMA review if numerous design changes were made during construction
Types of PFMAs

- Initial PFMA
- PFMA Review
- Design PFMA

- Construction PFMA
  - Evaluate operational procedures during construction.
  - Used to determine any construction activities that could cause dam to fail during construction.
How Many PFMs are Required?

• As many as you need!

• But there really is no real answer to this question

• More appropriate question: What PFMs are required to provide a full understanding of all threats to the safety of my project?

• You need as many PFMs as it takes
  – Concrete dams typically have fewer PFMs than Embankment Dams.
  – Putting a limit on PFMs defeats the PFMA process.
Tracking a Large Number of PFM\text{s}

- Concerns expressed over managing a large number of PFM\text{s}
Tracking a Large Number of PFM

- Managing a large number of PFM
  - Arrange according to loading condition
    » Normal (static) hydrologic, seismic, etc…
  - Arrange according to project feature
    » Embankment (s), spillway, gravity section, etc…
  - Arrange according to type of failure
    » Internal erosion, stability, overtopping, gates, etc…
Tracking a Large Number of PFMs

- Managing a large number of PFMs
  - Stay focused on one PFM at a time
  - Don’t jump between different loading condition or different structures
PFMA Report

• Reference Chapter 14 of the FERC Engineering Guidelines for proposed PFMA Report table of contents.

• Primary Purpose of the report is to document all discussions during the PFMA Workshop. If it is not in the report it was not discussed.

• Provides justification for what decisions are made regarding all PMFs.
PFMA Report

• Sketches should be used as frequently as possible
Do’s and Don’ts of PFMA
Potential Fatal Flaw PFMA Attitudes

• Avoid comment/attitude that dismisses open minds and open discussion
  – It’s always performed well, so it will always perform well
  – There is no way that is possible so we do not need to discuss it.
  – We have never had problems with that before, so we will not have any problems in the future
Potential Fatal Flaw PFMA Attitudes

• Any comment/attitude that promotes arrogance
  – We are wasting time even talking about this
  – That can’t happen
  – I’ve never seen that so I do not believe it can happen
Summary

• Hopefully this portrayed that the PFMA process is not extremely technical, since the process is not; however:
  – Most elements required detailed analyses.
  – Developing PFMs require detailed understanding of the design, construction, and operation of the project.
  – Engineers must remain open to possible flaws in a project.
  – Designers must remain open to critical reviews of their work.
  – The foundation and success of a dam safety program is dependent upon the quality of the PFMA.
Acknowledgments / Errata

- Additional information/references
  - FERC Chapter 14 of Engineering Guidelines
  - Bureau of Reclamation – Best Practices
  - US Army Corps of Engineers – Best Practices
  - ASDSO Web series by Doug Boyer
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